# Innovative design of soil pressure modeling test apparatus to determine the amount of soil compaction energy to dry density value

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# Innovative design of soil pressure modeling test apparatus to determine the amount of soil compaction energy to dry density value

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**Abstract**. A research in the laboratory about soil compaction is done using a hammer device, known as a standard proctor method and a modified proctor. Both methods use human strength to solidify the soil. This research is done well, because the compaction load and compactor height fall according to the research. Researchers tried to design and make a soil compactor with the same mold measure from standard proctor method but the compacting method use a hydraulic jack. So that the compressive strength and the energy can be measure to each layer. Thus the compacting energy can be measured and adjusted as needed. In addition, these results of compaction using a hydraulic jack will compare the soil compaction energy with standard proctor methods. The advantages of this new equipment can measure the compaction energy and dry density values. The research used modified press compactor test of 4 different pressures are 5 N/m$^2$; 10 N/m$^2$; 15 N/m$^2$ and 20 N/m$^2$. For every pressure conducted for 3 soil samples. After, the researcher will compare the soil compaction energy by standard proctor methode, new pressure test apparatus and with vehicle wheel pressure for soil compaction in the field.

## 1. Introduction

The urban infrastructure development project is to improve the economy of a region. To gate a good quality for the infrastruktur work, the planning and implementation construction must be suite to the required qualifications. A building that built on a flat area and has a solid soil will be easy to implement. However, the construction work is built in an unflat area and it will need excavation work and heaps (cut and fill). The soil compaction is a process in increasing the density of the soil by minimizing the distance between each particle, so it will cause an air volume reduction [1][2]. The removing air in the pores of the soil made the grains of the soil to become compressed. With this process, the soil compaction has expected to obtain stable soil and complete the technical requirements. To compac the soil material required several systems, for example, in the field is ussed a roller or compactor and in the laboratory using the proctor method. The density result depends on the water content of the soil material. The Compaction of the soil depends on mechanical manipulation, [3]. To obtain maximum dry density (MDD) require optimum water content (OMC) of the soil.

This research aims to develop science in civil engineering, especially in geotechnical sciences. Precisely this study using the capacity of the soil compation test equipment as standard proctor method. A new compaction test apparatus developed and modified to obtain compaction energy from a compaction. This modified soil compacting test to determine the energy coming out of the modified soil compaction method. If the energy obtained from compaction using a standard proctor method

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instrument is calculated by the amount of energy, but with this new modification, it is possible to know the amount of compaction energy. Another advantage is that it can shorten the time and energy, since the energy used can be measure during the soil compaction test. Surely, the private or government sector will require more accurate soil data. So far it only revolves around field investigations using sandcone test and standard proctor test and modified proctor in laboratory.

## 2. Research Methods

Proctor (1933) in Look, B.G., (2007) [4], and Hardiyatmo, HC. (2002) [5], has been observed that there is a definite connection between moisture content and solid dry volume weight for various soil types. The value of certain optimum moisture content obtained the value of the maximum dry volume weight ($\gamma_{dmak}$). The something between dry density ($\gamma_d$) with the weight of volume ($\gamma_b$) and moisture content (w) is shown in the equation of the energy required for compaction at standard compaction [5][6].

The manufacture of this compactor pressure tool is a modification of the laboratory standard compactor, the standard proctor method. This tool serves to solidify the soil, this compactor press is applied with a hydraulic jack that has a high compressive strength. The hydraulic system uses a manometer to be able to measure the pressure applied when the soil is under pressure. This means that while doing research, pressure energy can be measure. This tool is name modelling of modification compression test by pressure method. The study an availabel new design model of compression test used shown in Fig. 1.
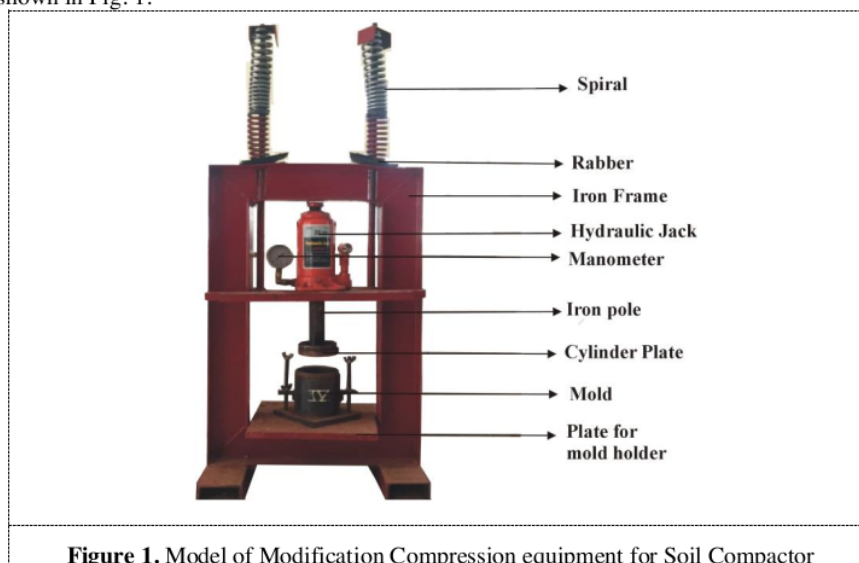


**Figure 1.** Model of Modification Compression equipment for Soil Compactor

The new equipment has 110 cm high, 40 cm long and 30 cm wide. The size is not too large and can only be used for research material by using fine-grained soil sample. The mould compactor that is a cylinder (mold), diameter 10.20 cm and 11.60 cm height. The soil sample in the mould is compacted with 2.50 kg a hammer and 30.50 cm a falling height. The soil is compaction 3 (three) layers with each layer 25 times the blow.

The first test is by standard proctor method test. After obtaining the optimum water content by proctor test, this water content is use in experiments with a new soil compactor. The preparation of the test sample is the same as the test system of standard proctor. The dry density after soil compaction

depends on the type of soil, moisture content, and energy provided by the hammer. Characteristics of soil density can be assessed by standard laboratory compaction tests.

A manual of the ground pressure tool is by pumping the hydraulic jack manually, the jack will push the plate down. Then the plate just below the jack will go down. When the jack is pumped the plate will press the soil inside the mold. When the soil has started compacted then the manometer will move, so it can know the amount of pressure received by the soil when reading the value on the manometer.

The first step of the study was to conduct a study of soil physical properties and research by standard proctor method to obtain maximum dry density ($\gamma_{dmak}$) and optimum water content ($w_{opt}$), [2][7]. After ($\gamma_d$) and (w) are obtained, the optimum water content becomes the reference as the water content used in the soil sample to be tested on a modified soil compacting test apparatus. After a soil samples containing optimum moisture content is ready and then the soil sample is fed into the mold divided into 3 layers. Each layer was press with the pressure already set. The pressure given for each specimen is 5 N/m$^2$; 10 N/m$^2$; 15 N/m$^2$ and 20 N/m$^2$.

## 3. Result and Discussion

Soil compaction is an attempt to increase the soil strength with a system to provide the load or pressure on the soil surface. As a result, for air and water contents contained in the void between the soils particles will come out of the void. The soil compaction test aims to determine the maximum dry density and optimum water content. Soil samples were took by undisturbed samples for testing properties and disturbed samples for proctor and modified compression test (new apparel) tests. The water content test result of undisturbed sample (SBM) is 20.80%. The density value is 1.29 gr/cm$^3$. The results of the soil analysis and plasticity index according to AASHTO Classification System and USCS, sample from borrow area of Sukabumi (SBM) is categorized sandy clay, The standard proctor procedure is performed according to ASTM D698 and AASHTO T90. While the soil samples from borrow area of Gedung Agung (GA) include the A-2-4 soil clusters of sandy clay soil and the soil is in accordance with the technical requirements as the preferred landfill, see figure 2.
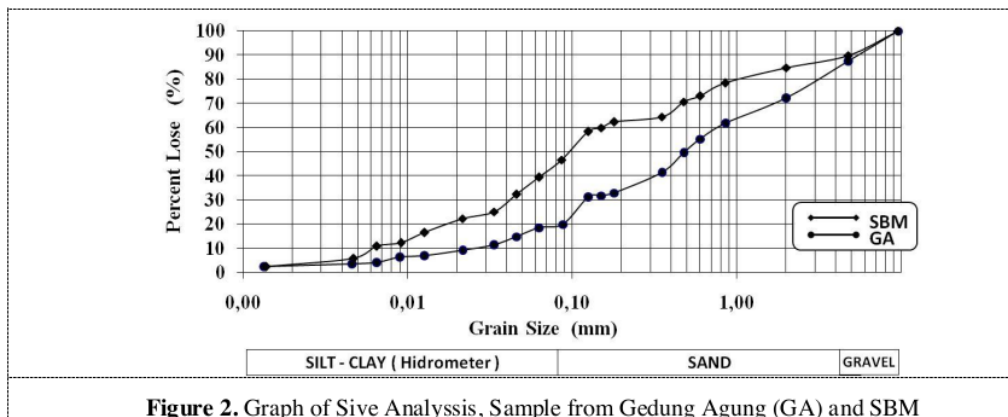


**Figure 2.** Graph of Sive Analyssis, Sample from Gedung Agung (GA) and SBM

In an experiment with a new test device, modification of compaction test by pressure methode, dry density values are obtained between 1.31 gr/cm$^3$ - 1.55 gr/cm$^3$ for pressure 5 N/m$^2$ - 20 N/m$^2$. Soil Data Result by Modification Compression Test, Sample of soil is from Sukabumi (SBM), see figur 3.

The result of standard proctor graphic for Soil Sample of Sukabumi (SBM) is the maximum dry density (MDD) value of 1.41gr/cm$^3$ and optimum moisture content (OMC) of 26%. The Standard Proctor experiment has produced the maximum dry density and optimum water content but it can also

calculate the compaction energy using formula energy [6]. The result is as formulated of compaction Energy [6] equals to 6.03 ft-lb/ft$^3$ or equal to 0.59 N/m$^2$. ($\approx$288.72 kJ/m$^3$).

Result of test undisturbed Soil sample from Gedung Agung got water content 20.80% and density is 1.62 gr/cm$^3$. Energy of compactor is as formulated 56.25ft-lb/ft$^3$ or 26.93 KJ/m$^3$, equivalent to 2.70 N/m$^2$. In this case, the compacting energy has equalized by pressure, because it has multiplied by the area of contact of the compactor. Experiment with modification compaction of pressure method using hydraulic jack for pressure 5 N/m2 - 20 N/m2 obtained dry density between 1.59 gr/cm$^3$ - 1.68 gr/cm$^3$ see, Fig. 4 and table 1. All dry density value of both the soil have different values, this is due to different physical characteristics. The soil may be use as a heap or other civil engineering work as required.

**Table 1**. Soil Data Result by Modification Compression Test, Sample of soil is from Sukabumi Bandar Lampung (SBM) dan Gedung Agung (GA)

| Test Result of the sample from Sukabumi deposit (SKM) | | | | | Test Result of the sample from Gedung Agung Deposit (GA) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Pressure | Code | Water | Dry | Zerro Air | Pressure | Code | Density | Water | Dry | Zerro Air |
| 5 MPa | SBM_5_1 | 25,03 | 1,31 | 1,55 | 5 MPa | GA_5_1 | 1,92 | 20,91 | 1,59 | 1,69 |
|  | SBM_5_2 | 23,66 | 1,31 | 1,59 |  | GA_5_2 | 1,91 | 21,16 | 1,58 | 1,68 |
|  | SBM_5_3 | 22,68 | 1,33 | 1,61 |  | GA_5_3 | 1,94 | 20,47 | 1,61 | 1,70 |
| 10 MPa | SBM_10_1 | 25,76 | 1,48 | 1,54 | 10 MPa | GA_10_1 | 1,96 | 20,60 | 1,62 | 1,70 |
|  | SBM_10_2 | 24,68 | 1,47 | 1,56 |  | GA_10_2 | 1,95 | 20,06 | 1,63 | 1,71 |
|  | SBM_10_3 | 26,11 | 1,48 | 1,53 |  | GA_10_3 | 1,96 | 19,77 | 1,64 | 1,72 |
| 15 MPa | SBM_15_1 | 25,07 | 1,52 | 1,55 | 15 MPa | GA_15_1 | 1,99 | 20,74 | 1,65 | 1,69 |
|  | SBM_15_2 | 24,34 | 1,53 | 1,57 |  | GA_15_2 | 2,01 | 20,50 | 1,67 | 1,70 |
|  | SBM_15_3 | 25,33 | 1,52 | 1,55 |  | GA_15_3 | 2,02 | 20,40 | 1,68 | 1,70 |
| 20 MPa | SBM_20_1 | 23,54 | 1,56 | 1,59 | 20 MPa | GA_20_1 | 2,03 | 20,71 | 1,68 | 1,69 |
|  | SBM_20_2 | 24,21 | 1,57 | 1,58 |  | GA_20_2 | 2,02 | 20,26 | 1,68 | 1,71 |
|  | SBM_20_3 | 25,36 | 1,55 | 1,55 |  | GA_20_3 | 2,04 | 19,77 | 1,70 | 1,72 |
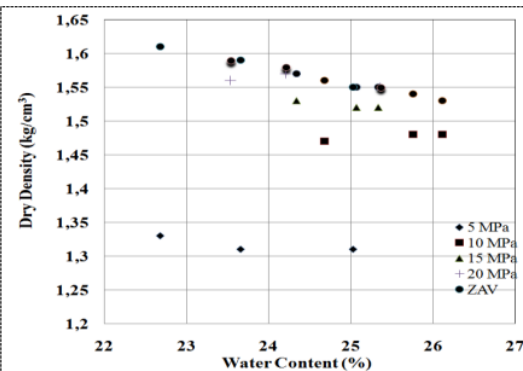


**Figure 3.** Relation of Dry Density with Moisture Content Based on Modification Compression Test, soil sample from Sukabumi Bandar Lampung (SBM).

In Figure 3 shows a graph of the experimental results from the Sukabumi stock using standard compaction proctor. It were obtained by maximum dry density of 1,37 gr/cm$^3$. Testing using a new equipment with the same soil sample obtained results 1.37 gr/cm$^3$ with the pressure as a compressive energy of 7 N/m$^2$.

Table 1 and figure 4 show that on the soil from the borrow area of Gedung Agung (GA) get the value of dry density of $\gamma_{dmax}$ 1.38 gr cm$^3$, this value is almost as large as the standard proctor compaction experiment and the new pressure tool is 1.37 gr/cm$^3$. In the other side, the experiment with

the new tool obtained the amount of press 7 N/m$^2$. This means that with a pressure of 7 N/m$^2$ to get dry density value of 1.37 gr/cm$^3$.
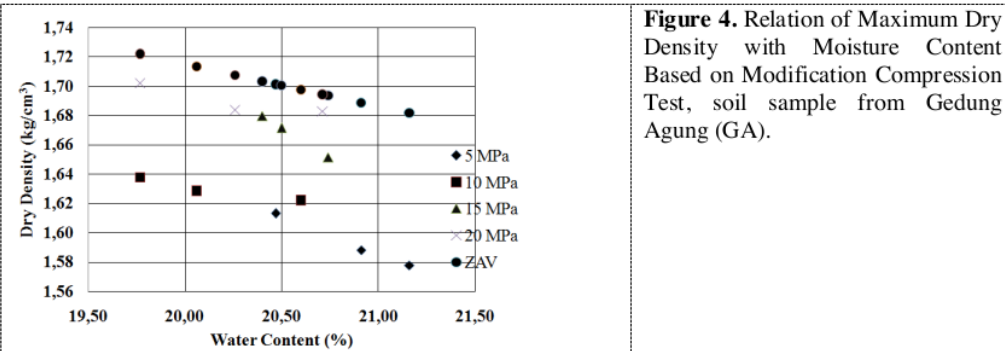


**Figure 4.** Relation of Maximum Dry Density with Moisture Content Based on Modification Compression Test, soil sample from Gedung Agung (GA).

Fig. 5 shows that, if the researche with a pressure modification compression test is given at 9 N/m$^2$, it will get a dry density value of 1.62 gr/cm$^3$. Whereas with the same sample, the dry density value is 1.58 gr/cm$^3$ of the standard Proctor test. This means that experiments with standard proctor obtained dry density values less than the modified compression test. But the new test tool can determine how the amount of energy the compactor will be applied in the field. Thus contractors and consultants and public works department governments can choose the type of equipment to be used for compaction in the field.
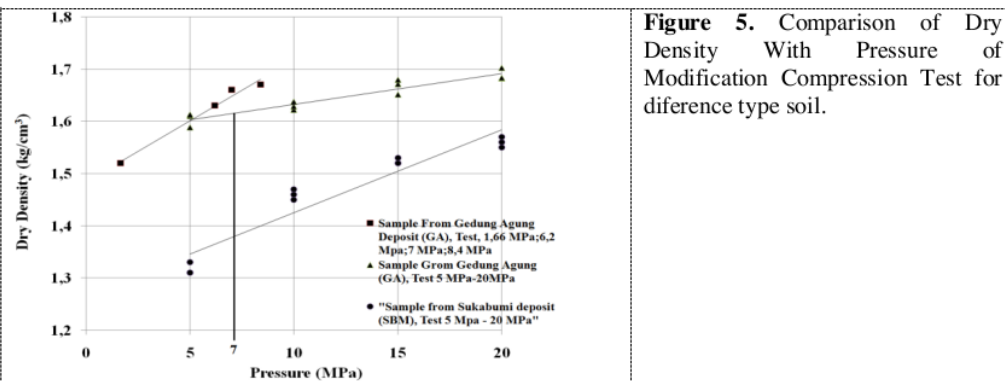


**Figure 5.** Comparison of Dry Density With Pressure of Modification Compression Test for diference type soil.

Another study, Hidayahtullah, A. 2018 [8] has conducted a soil compacting study with an energy of 1.66 N/m$^2$ - 10 N/m$^2$, the results show that the high energy provided by the soil becomes solid, at a pressure limit of 10 N/m$^2$ to 20 N/m$^2$ is the maximum value pressure which can be applied to the ground. Because the soil can not be compacted again and the soil provides resistance to the load given. This is due to the shrinking of the soil pores and the shrinkage of the water content in the sample. But at a pressure of 10 N/m$^2$ the dry density value stops so that it can be stated that the maximum dry density can be attained at 8.40 N/m$^2$ pressure. Particle of sand contained in the sample of Gedung Agung (GA), it is sand within stable aggregate, because sand could be in three different forms in the soil: sand that is within stable aggregates, sand that is within unstable aggregates and can easily be redistributed, and sand that is free [9]. Therefore the sample of Gedung Agung is better than the Sukabumi sample; it is shown from the compaction test result where the dry density value is greater.

This study proves that the pressure value on the roller compaction machine in the field is almost close to the pressure on the modified compression test of 7 $N/m^2$. This means that the new test equipment is a recommendation for the selection of heavy equipment in the field.

## 4. Conclusion

At the 5 $N/m^2$ pressure test, the water content (w) is relatively smaller than the pressure of 10 $N/m^2$, 15 $N/m^2$ and 20 $N/m^2$ due to the great loss of water. Standard laboratory proctor test obtained the value of maximum dry density ($\gamma_{dmax}$) of 1.4 $gr/cm^3$. When this value is converted to a modified compression test result or a new tool model with pressure using a hydroulic jack obtained a pressure value of 7 $N/m^2$. The larger the dry density ($\gamma d$) will decrease the water content (w) and dry air void density value.

The soil samples from Gedung Agung (GA) obtain the following results soil can be classified as embankments selected for underground layers. In the standard laboratory proctor test obtained a maximum dry density value of 1.62 $gr/cm^3$ and optimum mointure content of 20.8%. If this value is converted to a modified compression test in the laboratory, generate a pressure value of 9 $N/m^2$ obtained, this is shown in the Fig. 3. Pressure of 7 $N/m^2$ for regular embankment soil and 9 $N/m^2$ for the selected soil is the maximum pressure.

That mean, if water content increase to exceeds the optimal water content while the compaction energy is given continuously then what will occur is the value of the degree of soil density near zero air void. For this reason it is important to have good control over moisture content during compaction of soil layers in the field. A result of modeling the compaction metode with the use of hydraulick jacks as pressure and converted into energy quantities is very successful

## 5. Acknowledgment

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